NELSON BIGHORN SHEEP
Ovis canadensis nelsoni

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Management Status: Federal: None
California: Fully protected within the WMPA(CDFG, 1998)

General Distribution:

Bighorn sheep were originally distributed from Baja California to Texas in the south to the Canadian Rockies in the north, with the eastern boundary reaching western Nebraska and the western boundary in California extending from Mount Shasta in the north to the crest of the central and southern Sierra Nevada to the Transverse Ranges and the east side of the Peninsular Ranges in the south (Cowan, 1940). Traditional taxonomy dating back more than half a century (Cowan, 1940) broke bighorn sheep from the southwestern desert region into four subspecies, one of which, the Nelson Bighorn (*Ovis canadensis nelsoni*), included bighorn from the Transverse Ranges through most of the desert mountain ranges of California, including the WMPA, and adjacent Nevada and northern Arizona to Utah (Shackleton, 1985). Recent research (Ramey, 1993, 1995; Wehausen and Ramey, 1993) has found a lack of support for Cowan's (1940) desert subspecies and instead has found previously unrecognized north-south variation of the Nelson Bighorn (Wehausen and Ramey, 1993, 1999). The transition between the southern (warm desert) and the northern (cold desert) forms occurs in the middle of the WMPA, with I-15 east of Barstow representing the approximate boundary (Wehausen and Ramey, 1999). Whether these differences warrant taxonomic recognition remains to be determined, but they should be considered in conservation actions where possible and appropriate. However, within the WMPA no populations north of I-15 persist that have not been reintroduced or augmented with sheep from south of I-15.

Distribution in the West Mojave Planning Area:

Within the WMPA, 16 bighorn sheep populations are known to have existed as defined by mountain range complexes, or portions of one of these ranges. Five of these 16 areas no longer contain populations, three have been reintroduced, and two have been augmented with sheep from another population (Bleich et al., 1990a; Table 1, Figure 1). For the past decade, bighorn sheep populations in California have been viewed in a metapopulation context (Schwartz et al., 1986; Bleich et al., 1990b, 1996). Within the WMPA there are three metapopulations whose geographic boundaries are now formed by major fenced highways (I-15 and I-40) -- the south, central, and north Mojave Desert metapopulations (Torres et al., 1994, 1996).

Natural History:

Bighorn sheep have a large rumen, relative to body size (Krausman et al., 1993), which allows digestion of grasses, even in a dry state (Hanly, 1982). This gives them flexibility to select diets that optimize nutrient content from available forage. Consequently, bighorn sheep feed on a large variety of plant species and diet composition varies seasonally and among locations. The nutritional quality of their diet depends on growth activity of forage species and varies greatly among seasons, years, and locations (Wehausen and Hansen, 1988; Wehausen, 1992a), and is influenced greatly by precipitation and temperature (Wehausen, 1992b).

While diet quality in the Mojave Desert varies greatly among years, it is most predictably high in late winter and spring (Wehausen, 1992a), and this period coincides with the peak of lambing. Desert bighorn have a long lambing season that can begin in December and end in June in the Mojave Desert, and a small percentage of births commonly occur in summer as well (Thompson and Turner, 1982; Bunnell, 1982; Wehausen, 1991). Within the WMPA, the bighorn occurring north of I-15 have a later initiation of the lambing season than those further south (Wehausen and Ramey, 1999; Wehausen, 1991).

The primary breeding season in the WMPA occurs between August and November (Bleich et al., 1997), and the gestation period for bighorn sheep is about 174 days (Hass, 1995).

<u>Habitat Requirements</u>:

Basic to the biology of bighorn sheep is their agility on steep rocky terrain, an adaptation used to escape predators. Short legs, low center of gravity, and general stocky build are components aspects of this adaptation, but compromise fleetness necessary to predictably outrun coursing predators on less precipitous terrain. Consequently, within the desert, preferred habitat of bighorn is primarily on or near mountainous terrain above the desert floor. Also fundamental to the biology of bighorn sheep is the use of eyesight as the primary sense for detecting predators at sufficient distances to assure adequate time to reach safe terrain (Bleich et al., 1990b). Thus, preferred habitat of bighorn sheep is visually open, as well as steep and rocky. Because of scant rainfall and hot summer temperatures that limit most vegetation to low stature, most Mojave Desert mountain ranges satisfy these habitat requirements well.

Radio telemetry studies of bighorn sheep in various southwestern deserts, including the Mojave Desert of California, have found considerable movement of these sheep between mountain ranges (Bleich et al., 1990b). This is especially true of males, but also of ewes (Bleich et al., 1996). Within individual mountain ranges, populations often are small (Table 1). Levels of inbreeding could be high in such populations, but intermountain movements provide a genetic connection with a larger metapopulation, and this will counteract potential inbreeding problems (Schwartz et al., 1986; Bleich et al., 1990b). Intermountain movements also are the source of colonization of vacant habitat, which is fundamental to metapopulation dynamics and persistence. Colonization by ewes is the slow link in this process, but has recently been documented in two Mojave Desert ranges in California (Bleich et al., 1996; Torres et al., 1996). Consequently, intermountain areas of the desert floor that bighorn traverse between mountain ranges are as important to the long term viability of populations as are the mountain ranges themselves (Schwartz et al., 1986; Bleich et al., 1990b, 1996).

Surface water is another element of desert bighorn habitat considered to be important to population health (Turner and Weaver, 1980). Male and female bighorn sheep inhabiting desert ecosystems can survive without consuming surface water (Krausman et al., 1985), and males appear to drink infrequently in many situations (Jaeger et al., 1991; Bleich et al., 1997); however, there are no known large populations of bighorn sheep in the desert region that lack access to surface water.

It is common for males and females to segregate and occupy different habitats outside the breeding season (Bleich et al., 1997). Females tend to choose particularly steep, safe areas for bearing and initial rearing of lambs. In some situations they may even migrate to adjacent mountain ranges for this purpose (Jaeger, 1994). Areas of steep limestone are commonly preferred lambing areas if available. Males frequently occupy much less precipitous habitat during the lamb-rearing season (Bleich et al., 1997).

<u>Threats Analysis</u>:

Potential threats must be approached from the standpoint of individual populations and metapopulations. Actions that impair the ability of bighorn sheep to move between mountain ranges (e.g. fencing along highways or other boundaries, canals, and high densities of human habitation) will limit the potential for natural colonization and gene exchange, both of which are key to metapopulation viability.

Causes of population losses within the WMPA are unknown. Many bighorn sheep populations have disappeared in California and over much of their range during the past 140 years (Buechner, 1960; Wehausen et al., 1987a). While there is no single cause for these losses, pneumonia contracted from domestic sheep probably has been the greatest factor. All native populations were extirpated from northeastern California, northern Nevada, southwestern Idaho, Oregon, and Washington (Buechner, 1960) -- a region of extensive domestic sheep grazing. Further north in Canada and Alaska, where domestic sheep grazing has not been economical, the distribution of native sheep remains essentially unchanged. The history of bighorn sheep is replete with examples of major die-offs following contact with domestic sheep (Goodson, 1982; Foreyt and Jessup, 1982). Experiments have repeatedly confirmed that bighorn sheep are not compatible with strains of respiratory bacteria that are carried by healthy domestic sheep (Onderka and Wishart, 1988; Foreyt, 1989; Callan et al., 1991). For individual populations of bighorn sheep, domestic sheep grazing has the potential for the greatest devastation if contact with bighorn sheep occurs. This threat will exist anywhere that stray domestic sheep have a possibility of finding occupied bighorn sheep habitat.

Considerable predation by mountain lions (*Felis concolor*) on bighorn sheep has been documented for the Kingston, Clark, and Granite Mountains (Jaeger, 1994; Wehausen, 1996). In the Granite Mountains this caused a steep population decline to very low numbers (Wehausen, 1996). These populations lie just east of the WMPA, but all support populations of native or introduced deer, they primary prey of mountain lions. Deer are absent in almost all bighorn ranges within the WMPA. A notable exception is the San Bernardino Mountains, where considerable lion predation on bighorn sheep has been recently documented and appears to be causing population decline (S. Torres, unpubl. data).

Amounts of fall and winter precipitation strongly influence spring diet quality and reproductive success of bighorn sheep in the deserts of California (Wehausen et al., 1987b; Wehausen, 1992b). Consequently, long drought periods have the potential to cause population declines. However, high survivorship and longevity of ewes where mountain lion predation is lacking will tend to carry populations through such periods of low reproductive success (Wehausen, 1992a).

A disease syndrome has been documented for some bighorn sheep populations in the Mojave and Sonoran deserts of California that results in an unusually high mortality of lambs in spring from pneumonia (DeForge and Scott, 1982; DeForge et al., 1982; Wehausen et al., 1987b). This disease process can persist for many years and result in substantial population declines (DeForge et al., 1995). As with drought, high longevity of females, coupled with a small amount of recruitment, can carry populations through such episodes, provided that major recruitment pulses occur periodically (Wehausen, 1992a).

The etiology of this disease syndrome is not fully understood. Two gnat-born viruses causing hemorrhagic diseases (bluetongue, BT, and epizootic hemorrhagic disease, EHD), one influenza virus (parainfluenza - 3, PI-3) and a pox virus (contagious ecthyma, CE) have been implicated in this disease process (DeForge et al., 1982), and all but EHD have been isolated from sick lambs (J. DeForge, unpubl. data). In this disease syndrome lambs die of bacterial pneumonia, a secondary infection in a disease process apparently initiated by a virus. It is probable that some of the implicated viruses are also opportunists, rather than initiators. The ultimate cause of this disease process is the initiating organism, but the specific organism remains unknown. Wehausen (1992a) noted for two populations in the Mojave Desert suffering from this disease syndrome that there was a negative relationship between spring diet quality and lamb survival. This is contrary to the expected relationship based on nutrition, and suggests that an insect vector population that benefits from rainfall is involved; thus, the two insect-vectored hemorrhagic viruses are likely candidates. Also supporting this idea of involvement of an insect vector are findings that this disease syndrome can disappear following a very dry year (Wehausen et al., 1987b). This also occurred in two populations following 1990 (Wehausen, 1992a; DeForge et al., 1995). Cattle have long been associated with BT and were thought to serve as the virus reservoir; however, this role of cattle is no longer supported (Barrat-Boyes and MacLachlan, 1995). The role that cattle may play in this disease process that causes high mortality of bighorn lambs is not clear.

Competition for surface water is another factor thought to cause population declines. Usurpation of water sites by humans is an obvious example. Bighorn sheep can show a general social intolerance of large ungulates like cattle (Horejsi, 1975; Wilson, 1975), and the potential influences of cattle and feral burros also have been considered in this light. Both of these non-native species have been inferred to cause bighorn to abandon use of water sources (Dunn and Douglas, 1982; Wehausen, 1988; Dunn, 1993). However, such displacement constitutes competition only if water thereby becomes in short supply for the bighorn resulting in population decline. This has not been documented, and Wehausen and Hansen (1986) and King and Workman (1984) noted that cattle and bighorn largely remain spatially separated due to different habitat preferences. This niche separation is less for burros and, where they occur at high population densities, this feral equid may compete with bighorn sheep for forage and/or water in some situations. However, a negative influence of burros on bighorn sheep demography has not been shown as support for true competition.

Loss of surface water sources within existing and historic bighorn sheep ranges may diminish the viability of existing populations or the potential for successful reintroduction or natural colonization where this species is absent. The influence of the loss of any particular water source will depend on the number of water sources available to bighorn sheep. Water sources can be lost to bighorn sheep due to various causes, including domestic and feral stock use.

<u>Biological Standards</u>:

Bighorn sheep have suffered considerable population declines in the past 140 years, as evidenced by vacant habitat within the WMPA. In addition, metapopulations have been fragmented (Bleich et al., 1996). Long term viability of these metapopulations will be best ensured by preventing further population losses and fragmentation, and by restoring populations in vacant historic habitat. Artificial enhancement of populations (e.g. water developments) may be necessary in some cases to promote natural and induced colonization.

BLM (1992) issued an Instruction Memorandum on the management of domestic and bighorn sheep based on the consensus of a workshop representing all concerned parties. That document stated that:

> "No domestic sheep grazing should be allowed within buffer strips less than 9 mi. (13.5 km) surrounding desert bighorn habitat, except where topographic features or other barriers prevent physical contact."
>
> "Domestic sheep trailed and grazed outside the 9 mi. (13.5 km) buffer and in the vicinity of desert bighorn ranges should be closely managed and carefully herded."

These recommendations should be adhered to with the goal of preventing any contact between domestic and bighorn sheep to prevent further losses of populations from this cause.

Key water sources within current and historic bighorn sheep habitat should be closely monitored and enhanced as needed to ensure reliable provision of water during the summer months. Since water sources may also enhance the populations of predators of bighorn sheep (S. Cunningham, pers. comm.), this should be limited to a number deemed adequate to sustain each bighorn sheep population. Water enhancement in mountain ranges may promote development of large bighorn populations in some situations. These large populations, in turn, may produce natural colonists that reestablish populations in vacant habitat, and provide reintroduction stock to reestablish populations.

Desert bighorn metapopulations in the WMPA have already suffered considerable fragmentation from fenced highways, aqueducts, and losses of some populations (Bleich et al., 1996). Further division of metapopulations should not be allowed and historic habitat should be restocked to maximize connectivity and the number of populations in remaining metapopulations when reintroduction stock is available. Bleich et al. (1990) made specific recommendations on this that apply to the WMPA, and concluded that existing metapopulations can remain viable if adequately managed, including maintenance of intermountain travel corridors. Nevertheless, opportunities to reestablish connections across recent artificial barriers that now define metapopulations should be considered.

<u>Literature Cited</u>:

Barratt-Boyes, S.M., and N.J. MacLachlan. 1995. Pathogenesis of bluetongue virus infection of cattle. J. Amer. Vet. Med. Assoc. 206:1322-1329.

Bleich, V.C., R.T. Bowyer, and J.D. Wehausen. 1997. Sexual segregation in mountain sheep: resources or predation? Wildl. Mongr. No. 134. 50pp.

Bleich, V.C., J.D. Wehausen, K.R. Jones, and R.A. Weaver. 1990a. Status of bighorn sheep in California, 1989 and translocations from 1971 through 1989. Desert Bighorn Counc. Trans. 34:24-26.

Bleich, V.C., J.D. Wehausen, and S.A. Holl. 1990b. Desert-dwelling mountain sheep: conservation implications of a naturally fragmented distribution. Conserv. Biol. 4:383-390.

Bleich, V.C., J.D. Wehausen, R.R. Ramey II, and J.L. Rechel. 1996. Metapopulation theory and mountain sheep: implications for conservation. pp. 453-473, *In:* D. R. McCullough, (ed.), Metapopulations and wildlife conservation management. Island Press, Washington, D.C.

Buechner, H.K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildl. Monogr. No. 4. 174pp.

Bunnell, F.L. 1982. The lambing period of mountain sheep: synthesis, hypotheses, and tests. Can. J. Zool. 60:1-14.

Bureau of Land Management. 1992. Guidelines for domestic sheep management in bighorn sheep habitats. Instruction Memorandum No. 92-264 (June 18) from the Director, Washington, D.C.

Callan, R.J., T.D. Bunch, G.W. Workman, and R.E. Mock. 1991. Development of pneumonia in desert bighorn sheep after exposure to a flock of exotic wild and domestic sheep. J. Amer. Vet. Med. Assoc. 198:1052-1056.

Cowan, I. McT. 1940. Distribution and variation in the native sheep of North America. Amer. Midl. Nat. 24:505-580.

DeForge, J.R., and J.E. Scott. 1982. Ecological investigations into high lamb mortality. Desert Bighorn Counc. Trans. 26:65-76.

DeForge, J.R., D.A. Jessup, C.W. Jenner, and J.E. Scott. 1982. Disease investigations into high lamb mortality of desert bighorn in the Santa Rosa Mountains, California. Desert Bighorn Counc. Trans. 26:76-81.

DeForge, J.R., E.M. Barrett, S.D. Ostermann, M.C. Jorgensen, and S.G. Torres. 1995. Population dynamics of peninsular bighorn sheep in the Santa Rosa Mountains, California, 1983-1994. Desert Bighorn Counc. Trans. 39:50-67.

Dunn, W.C. 1993. Use of springs by desert bighorn sheep before and after removal of feral burros. Desert Bighorn Counc. Trans. 37:11-15.

Dunn, W.C. and C.L. Douglas. 1982. Interaction between desert bighorn sheep and feral burros at spring areas in Death Valley. Desert Bighorn Counc. Trans. 26:87-96.

Foreyt, W.J. 1989. Fatal *Pasteurella haemolytica* pneumonia in bighorn sheep after direct contact with clinically normal domestic sheep. Amer. J. Vet. Res. 50:341-344.

Foreyt, W.J., and D.A. Jessup. 1982. Fatal pneumonia of bighorn sheep following association with domestic sheep. J. Wildl. Dis. 18:163-168.

Goodson, N.J. 1982. Effects of domestic sheep grazing on bighorn sheep populations: a review. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:287-313.

Hanly, T.A. 1982. The nutritional basis for food selection by ungulates. J. Range Manage. 35:146-151.

Hass, C.C. 1995. Gestation periods and birth weights of desert bighorn sheep in relation to other caprinae. Southwest. Nat. 40:139-147.

Horejsi, B.L. 1975. Discussion. p. 103, *In:* J. B. Trefethen, (ed.), The wild sheep in modern North America. The Winchester Press, New York.

Jaeger, J.R. 1994. Demography and movements of mountain sheep (*Ovis canadensis nelsoni*) in the kingston and Clark Mountain ranges, California. M.S. Thesis, Univ. of Nevada, Las Vegas. 64pp.

Jaeger, J.R., J.D. Wehausen, and V.C. Bleich. 1991. Evaluation of time-lapse photography to estimate population parameters. Desert Bighorn Counc. Trans. 35:5-8.

King, M.M., and G.W. Workman. 1984. Cattle grazing in desert bighorn sheep habitat. Desert Bighorn Counc. Trans. 28:18-22.

Krausman, P.R., J.D. Wehausen, M.C. Wallace, and R.C. Etchberger. 1993. Rumen characteristics of desert races of mountain sheep and desert mule deer. Southwest. Natur. 38:172-174.

Krausman, P.R., S. Torres, L.L. Ordway, J.J. Hervert, and M. Brown. 1985. Diel activity of ewes in the Little Harquahala Mountains, Arizona. Desert Bighorn Counc. Trans. 29:24-26.

Onderka, D.K., and W.D. Wishart. 1988. Experimental contact transmission of *Pasteurella haemolytica* from clinically normal domestic sheep causing pneumonia in Rocky Mountain bighorn sheep. J. Wildl. Dis. 24:663-667.

Ramey, R.R. II. 1993. Evolutionary genetics and systematics of North American mountain sheep. Ph.D. Thesis, Cornell Univ., Ithaca, NY.

Ramey, R.R. II. 1995. Mitochondrial DNA variation, population structure, and evolution of mountain sheep in the south-western United States and Mexico. Mol. Ecol. 4:429-439.

Schwartz, O.A., V.C. Bleich, and S.A. Holl. 1986. Genetics and the conservation of mountain sheep *Ovis canadensis nelsoni*. Biol. Conserv. 37:179-190.

Shackleton, D.M. 1985. Ovis canadensis. Mammalian Species 230:1-9.

Thompson, R.W., and J.C. Turner. 1982. Temporal geographic variation in the lambing season of bighorn sheep. Can. J. Zool. 60:1781-1793.

Torres, S.G., V.C. Bleich, and J.D. Wehausen. 1994. Status of bighorn sheep in California, 1993. Desert Bighorn Counc. Trans. 38:17-28.

Torres, S.G., V.C. Bleich, and J.D. Wehausen. 1996. Status of bighorn sheep in California - 1995. Desert Bighorn Counc. Trans. 40:27-34.

Turner, J.C., and R.A. Weaver. 1980. Water. pp. 100-112, *In:* G. Monson and L. Sumner, (eds.), The desert bighorn. Univ. of Arizona Press, Tucson, Arizona.

Wehausen, J.D. 1988. Cattle impacts on mountain sheep in the Mojave Desert: report II. Unpubl. report, Calif. Dept. of Fish and Game, Sacramento. 52pp.

Wehausen, J.D. 1991. Some potentially adaptive characters of mountain sheep populations in the Owens Valley region. pp. 256-267, *In:* C.A. Hall, Jr., V. Doyle-Jones, and B. Widawski, (eds.), Natural history of eastern California and high-altitude research. White Mountain Research Sta. Symp. Vol. 3., Bishop, California.

Wehausen, J.D. 1992a. Demographic studies of mountain sheep in the Mojave Desert: report IV. Unpubl. report, Calif. Dept. of Fish and Game, Sacramento. 54pp.

Wehausen, J.D. 1992b. The role of precipitation and temperature in the winter range diet quality of mountain sheep of the Mount Baxter herd, Sierra Nevada. Bienn. Symp. North. Wild Sheep and Goat Counc. 8:279-292.

Wehausen, J.D. 1996. Effects of mountain lion predation on bighorn sheep in the Sierra Nevada and Granite Mountains of California. Wildlife Soc. Bull. 24:471-479.

Wehausen, J.D., and M.C. Hansen. 1986. Impacts of cattle grazing on bighorn sheep. Unpubl. report, Calif. Dept. of Fish and Game, Sacramento.

Wehausen, J.D., and M.C. Hansen. 1988. Plant communities as the nutrient base of mountain sheep populations. pp. 256-268, *In:* C.A. Hall, Jr., and V. Doyle-Jones, (eds.), Plant

biology of eastern California. Natural history of the White-Inyo Range symposium Vol. 2. White Mountain Research Station, Bishop, Calif.
Wehausen, J.D., and R.R. Ramey II. 1993. A morphometric reevaluation of the peninsular bighorn subspecies. Desert Bighorn Counc. Trans. 37:1-10.
Wehausen, J.D. and R.R. Ramey II. 1999. Further morphometric analyses of mountain sheep in southwestern United States and Mexico: a report to cooperators. pp. 215-246, *In:* F.J. Singer and M.A. Gudorf, (eds.), Restoration of bighorn sheep metapopulations in and near 15 national parks: conservation of a severely fragmented species, Vol III. USGS Open file report 99-102.
Wehausen, J.D., V.C. Bleich, and R.A. Weaver. 1987a. Mountain sheep in California: a historical perspective on 108 years of full protection. Trans. West. Section Wildl. Soc. 23:65-74.
Wehausen, J.D., V.C. Bleich, B. Blong, and T.L. Russi. 1987b. Recruitment dynamics in a southern California mountain sheep population. J. Wildl. Manage. 51:86-98.
Wilson, L.O. 1975. Discussion. pp. 103-105, *In:* J.B. Trefethen, (ed.), The wild sheep in modern North America. The Winchester Press, New York.

Table 1. Mountain ranges in the WMPA known to have supported bighorn sheep populations, and population status in 1995 (Torres et al. 1994, 1996). Classification codes are: E=extinct; R=reintroduced population; A=augmented native population; N=native population.

Mountain Range	**Classification**	**Size**
A. North Mojave Metapopulation		
Coso	E	0
Argus/Slate	R	51-100
Eagle Crags	R	<25
Granite/Quail	E	0
Avawatz	A	51-100
Soda	E	0
B. Central Mojave Metapopulation		
Cady	N	25-50
C. South Mojave Metapopulation		
Bullion	R	<25
Newberry/Ord	N	25-50
Rodman	E	0
Sheephole	A	51-100
Pinto	E	0
Queen	N	25-50
Little San Bernardino	N	101-150
South San Bernardino	N	101-150
North San Bernardino	N	<25